Testing in Resource Constrained Execution Environments

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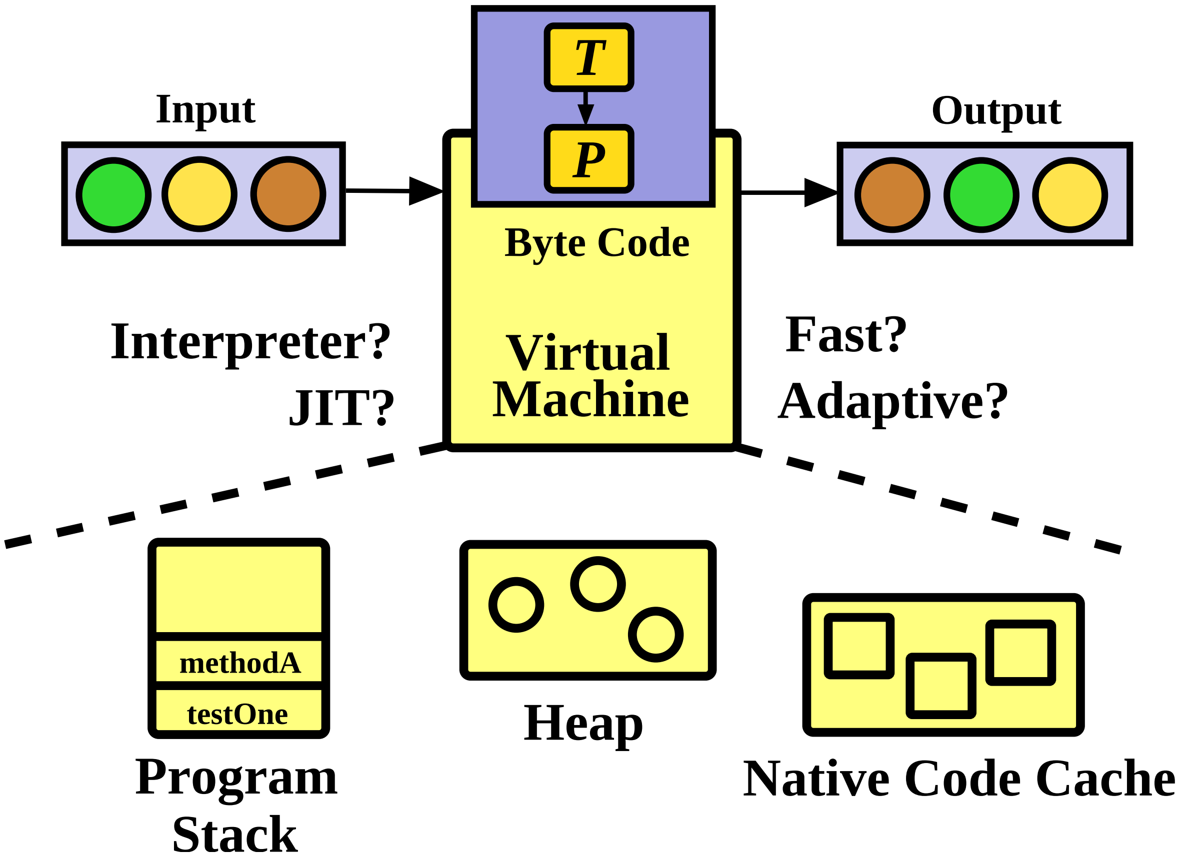
Contributions

- Use of native code unloading during test suite execution in a resource constrained environment
- Identification of the testing techniques that yield the greatest reduction in execution time and native code size
- Characterization of how software applications and test suites restrict and/or support resource constrained testing
- Cost-benefit analysis for the use of sample-based and exhaustive profiles of program testing behavior
- **Executes test suites faster when memory resources are limited!**

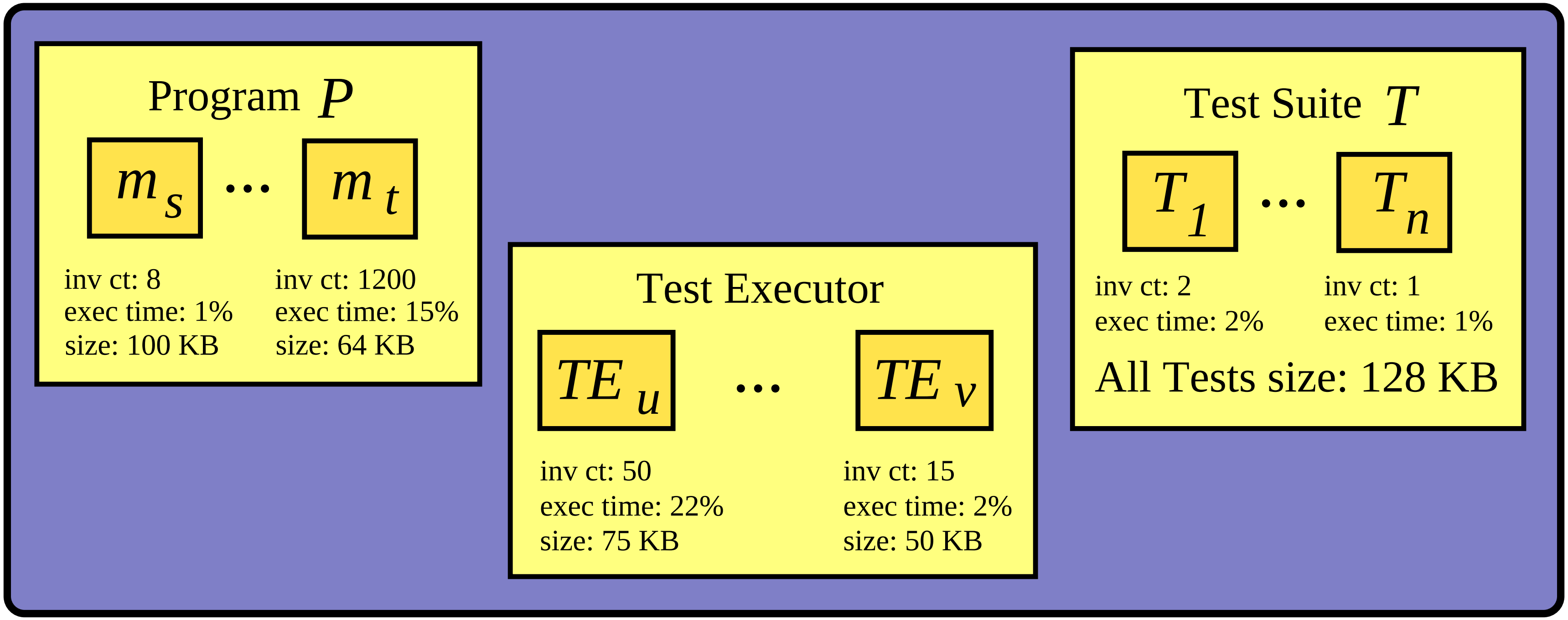
Test Suite Execution with a JVM



- During testing the JVM must manage limited resources

Resource Constrained Testing

Memory Resident Native Code Bodies



- JIT compiler produces native code that exhausts limited memory resources
- Frequent invocation of GC increases testing time

Test Suite Execution Strategies

- **Omit tests?** - Could reduce overall confidence in the correctness of P
- **Use non-constrained environment?** - Defects related to P's interaction with environment might not be isolated
- **Execute tests individually?** - Might increase overall testing time and violate test order dependencies
- **Unload with offline profile?** - Not useful if P and T change frequently during regression testing
- **Our Approach**: Use online behavior profiles to guide the unloading of native code

Experiment Goals and Design

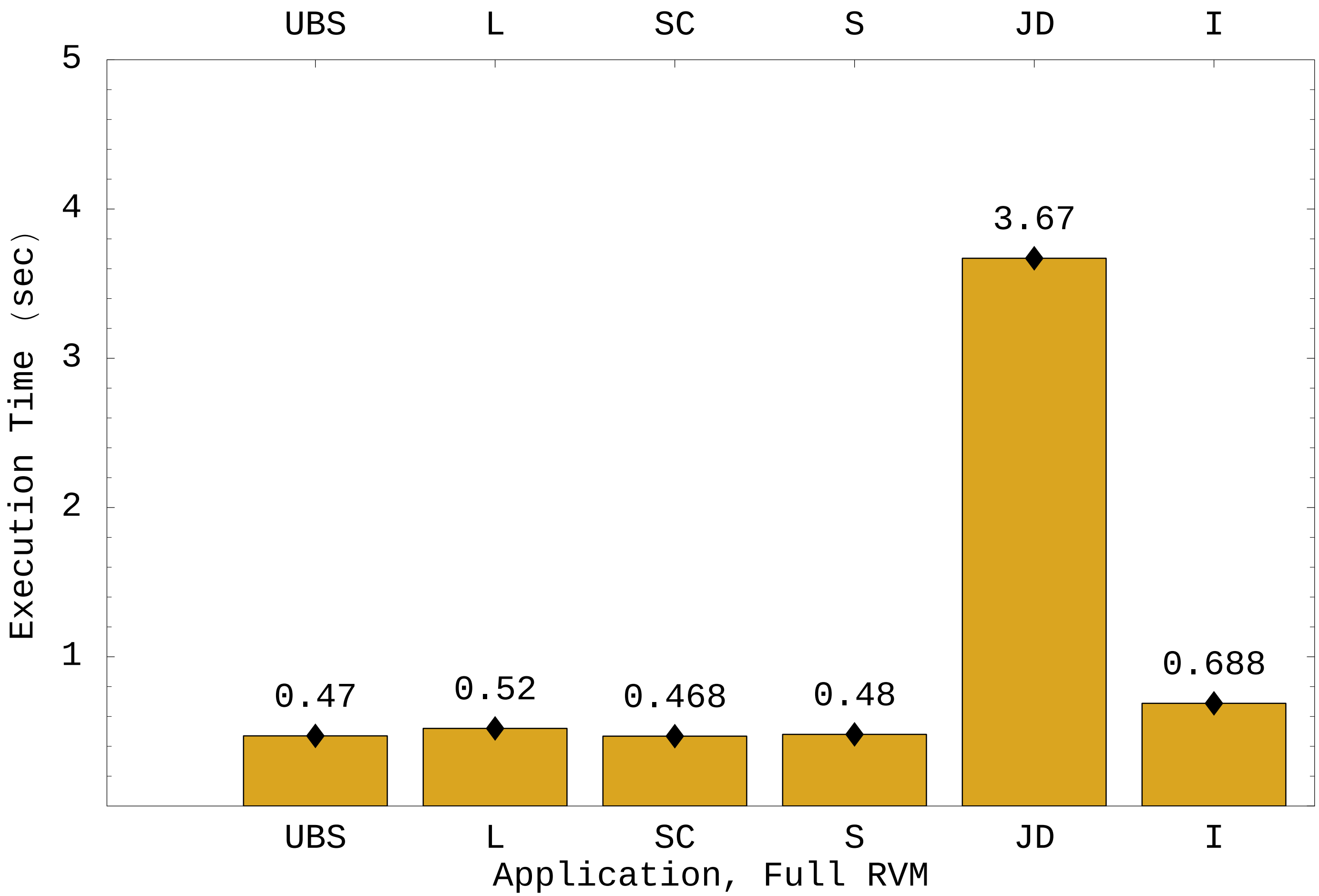
- **Research Question:** Can an adaptive code unloading JVM reduce time and space overheads associated with memory constrained testing?
- **Experiment Metrics**: percent reduction in time, $\mathcal{T}_R^{\%}(P, T)$ and space, $\mathcal{S}_R^{\%}(P, T)$
- Jikes RVM 2.2.1, JUnit 3.8.1, GNU/Linux 2.4.18
- Sample-based (*S*) and exhaustive (*X*) program profi les
- Timer (*TM*), garbage collection (*GC*), and code cache size (*CS*) triggers the unloading technique

Case Study Applications

Name	*Min* Size (MB)	# Tests	NCSS
`UniqueBoundedStack` (UBS)	8	24	362
`Library` (L)	8	53	551
`ShoppingCart` (SC)	8	20	229
`Stack` (S)	8	58	624
`JDepend` (JD)	10	53	2124
`IDTable` (ID)	11	24	315

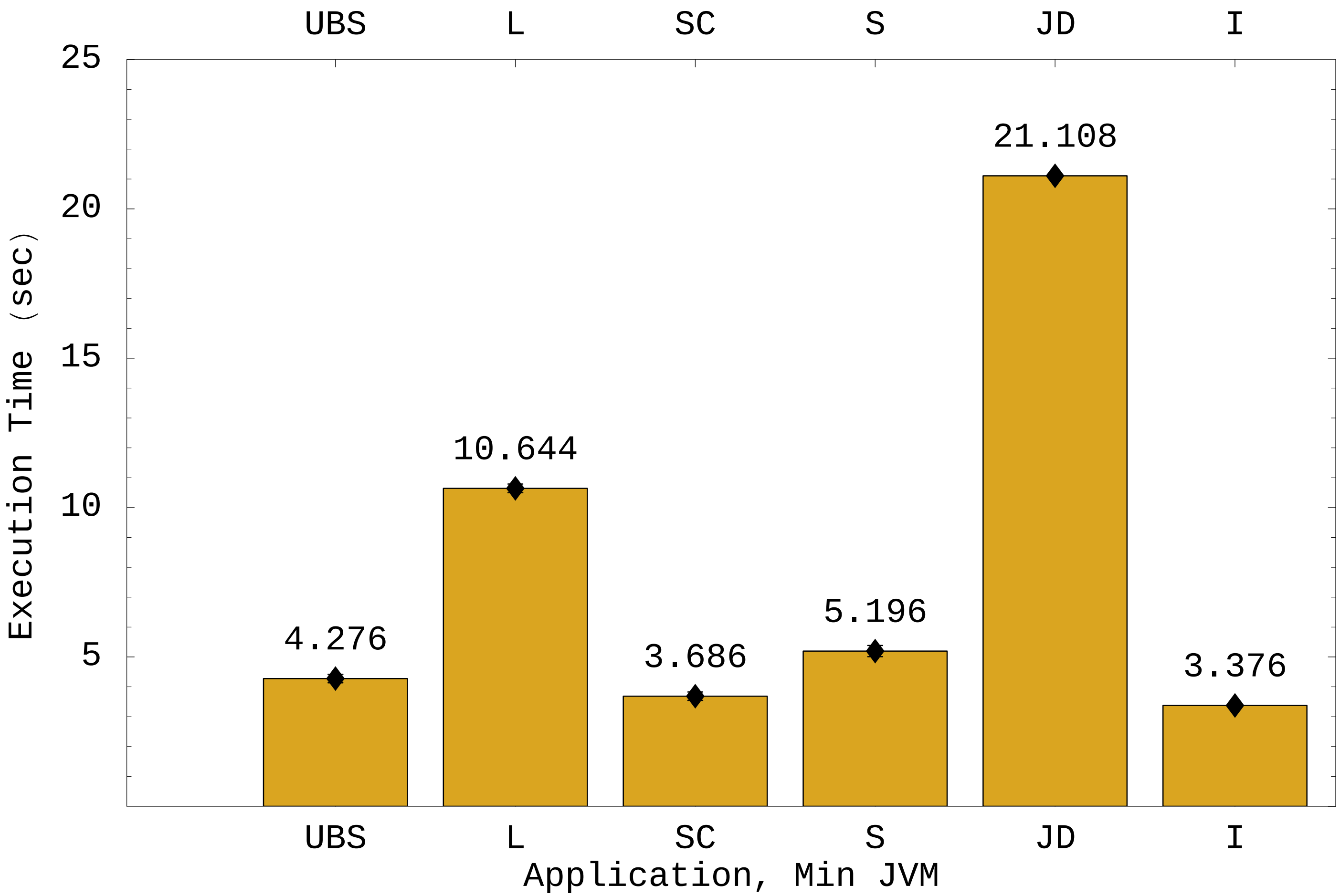
- Empirically determined the *MIN* Jikes RVM heap size

Testing Time Overhead: *Full* RVM



- When memory is not constrained, testing time is acceptable

Testing Time Overhead: *Min* RVM



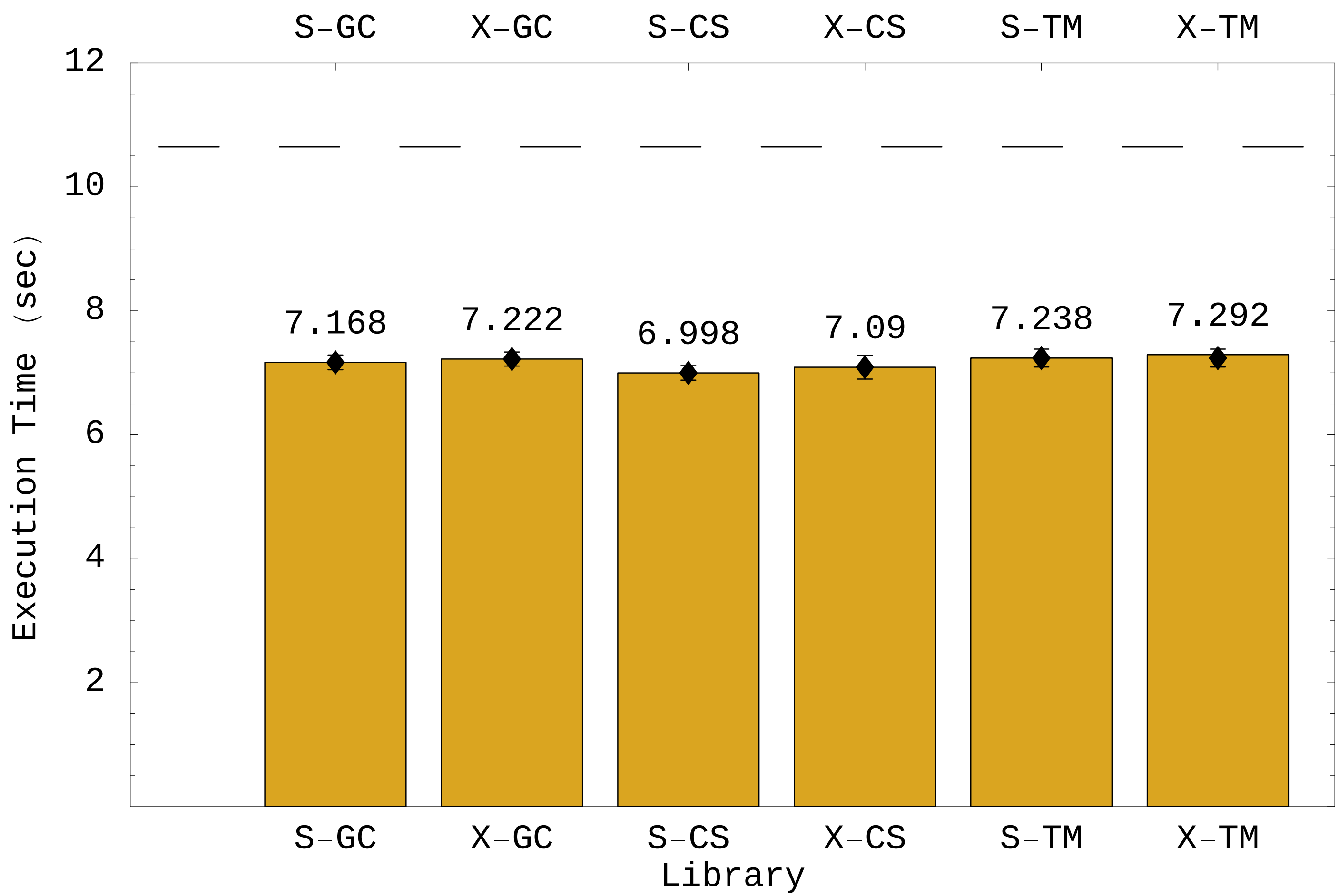
- Testing time increases signifi cantly when memory is *Min*

Summary of Reductions for `Library`

Name	$\mathcal{T}_R^{\%}(P,T)$	$\mathcal{S}_R^{\%}(P,T)$
S-GC	32.7	78.8 ✓
X-GC	32.1	65.0
S-TM	32.0	72.8
X-TM	31.5	62.3
S-CS	34.3 ✓	61.4
X-CS	33.4	59.8

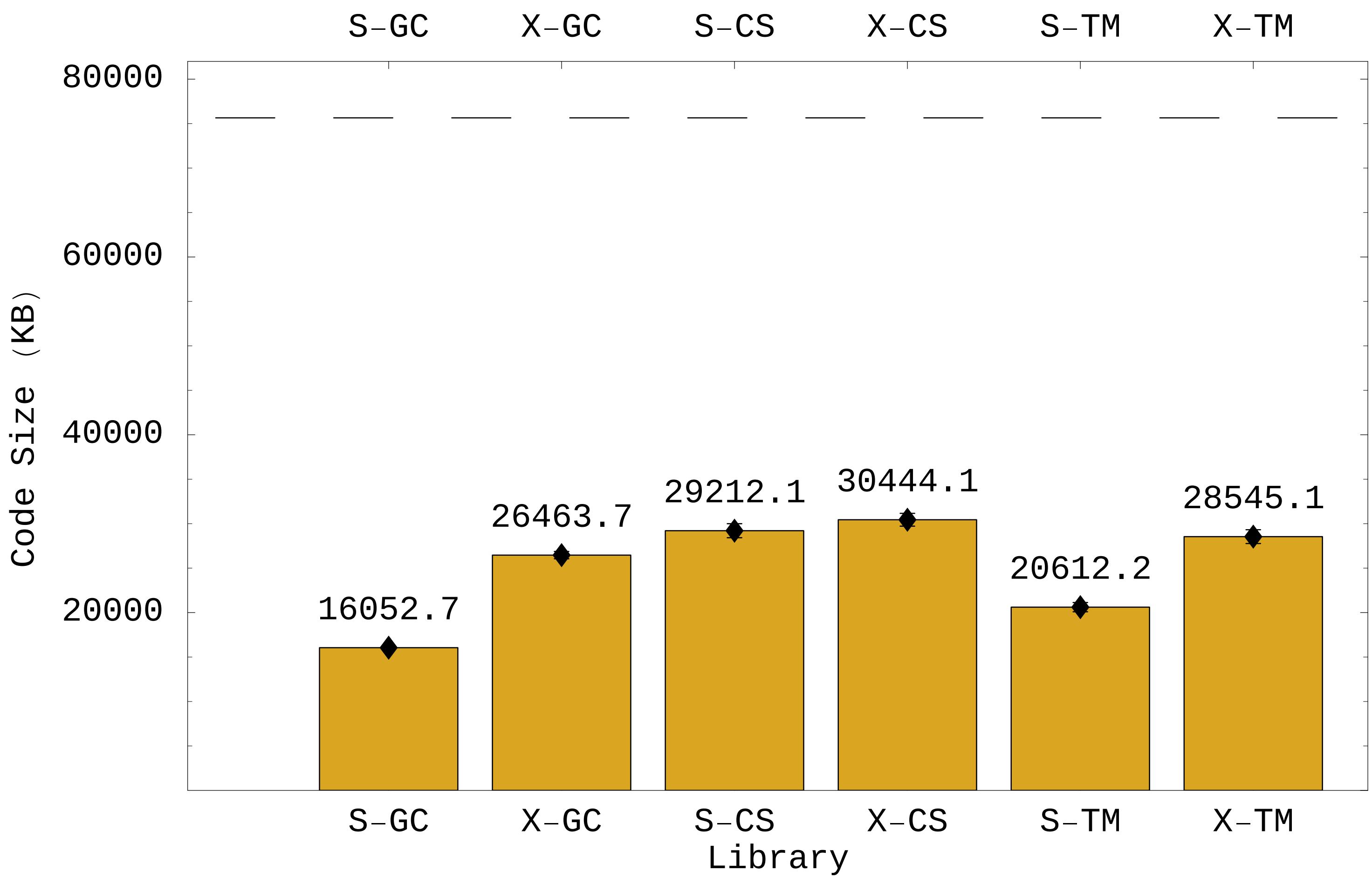
- Signifi cant reductions in time and space required for testing

Testing Time Overhead: Library



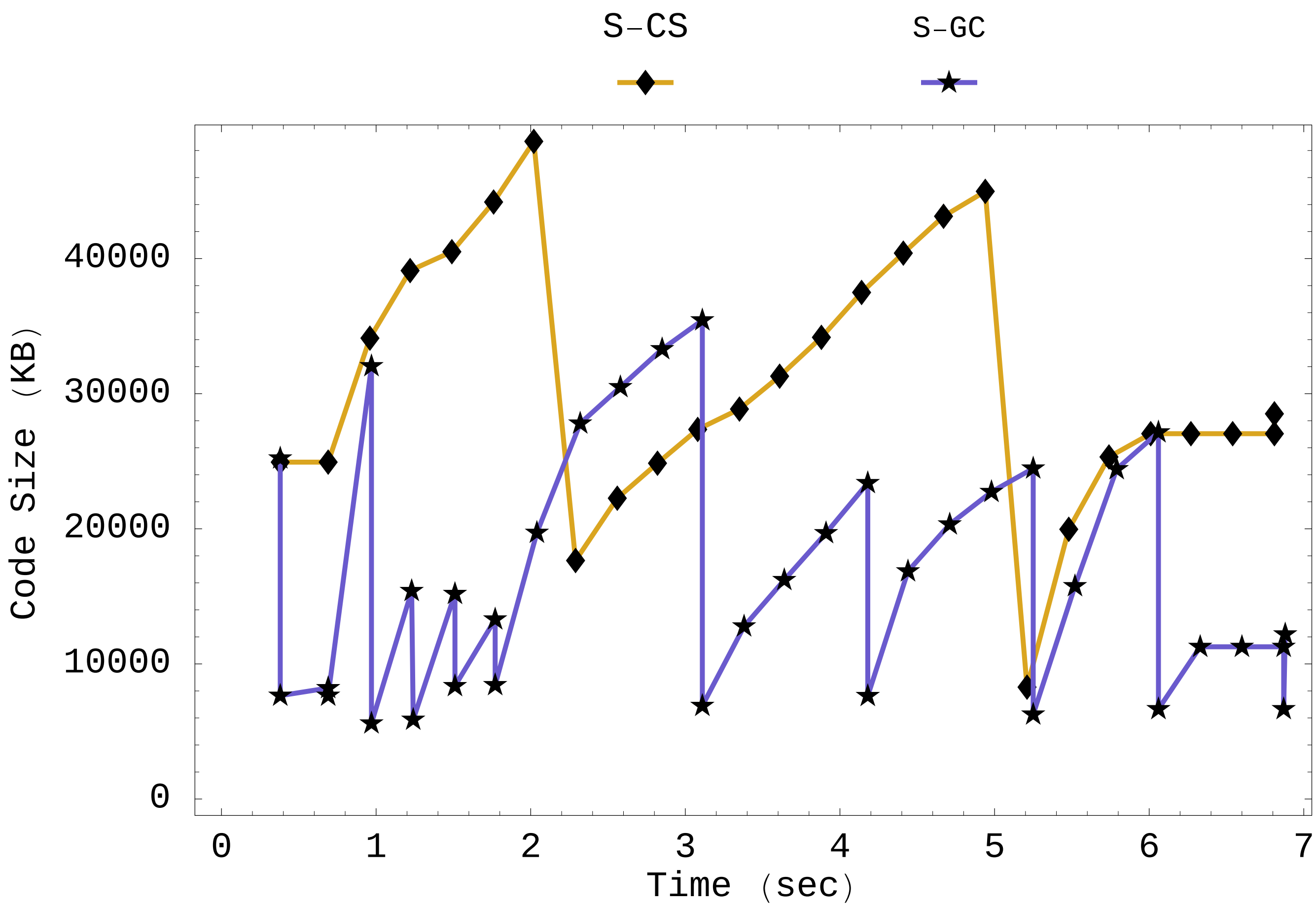
- *S* vs. *X*: Similar reductions for all code unloading techniques

Testing Space Overhead: Library



- Code size reduction does not always yield best testing time

Code Size Fluctuation: `Library`



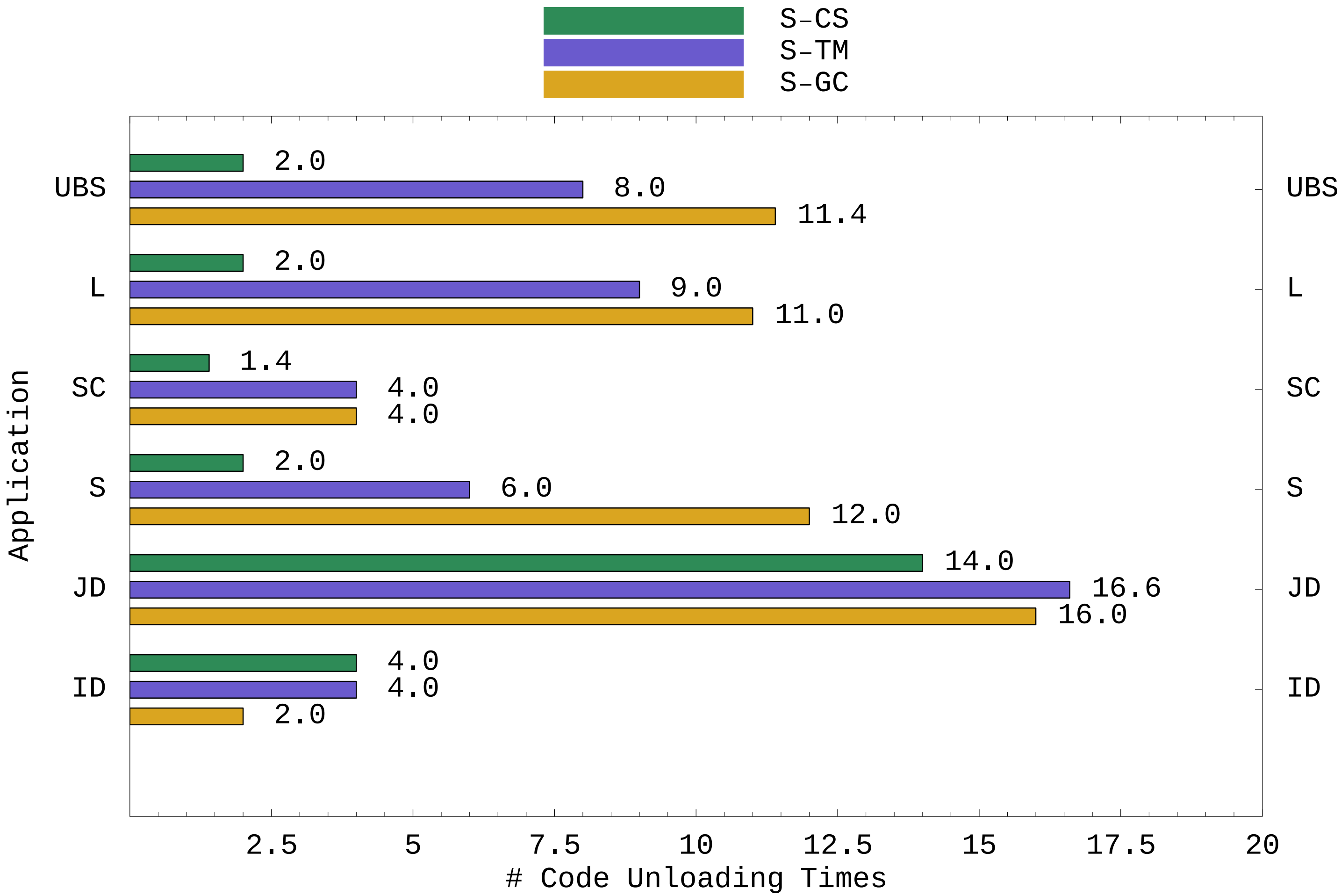
- *S-GC* causes code size fluctuation that increases testing time

Summary of Reductions for `ID`

Name	$\mathcal{T}_R^{\%}(P,T)$	$\mathcal{S}_R^{\%}(P,T)$
S-GC	-1.1	42.5
X-GC	-1.1	26.7
S-TM	-1.2	44.5
X-TM	-.29 ✓	28.8
S-CS	-.77	51.4
X-CS	-1.4	61.4 ✓

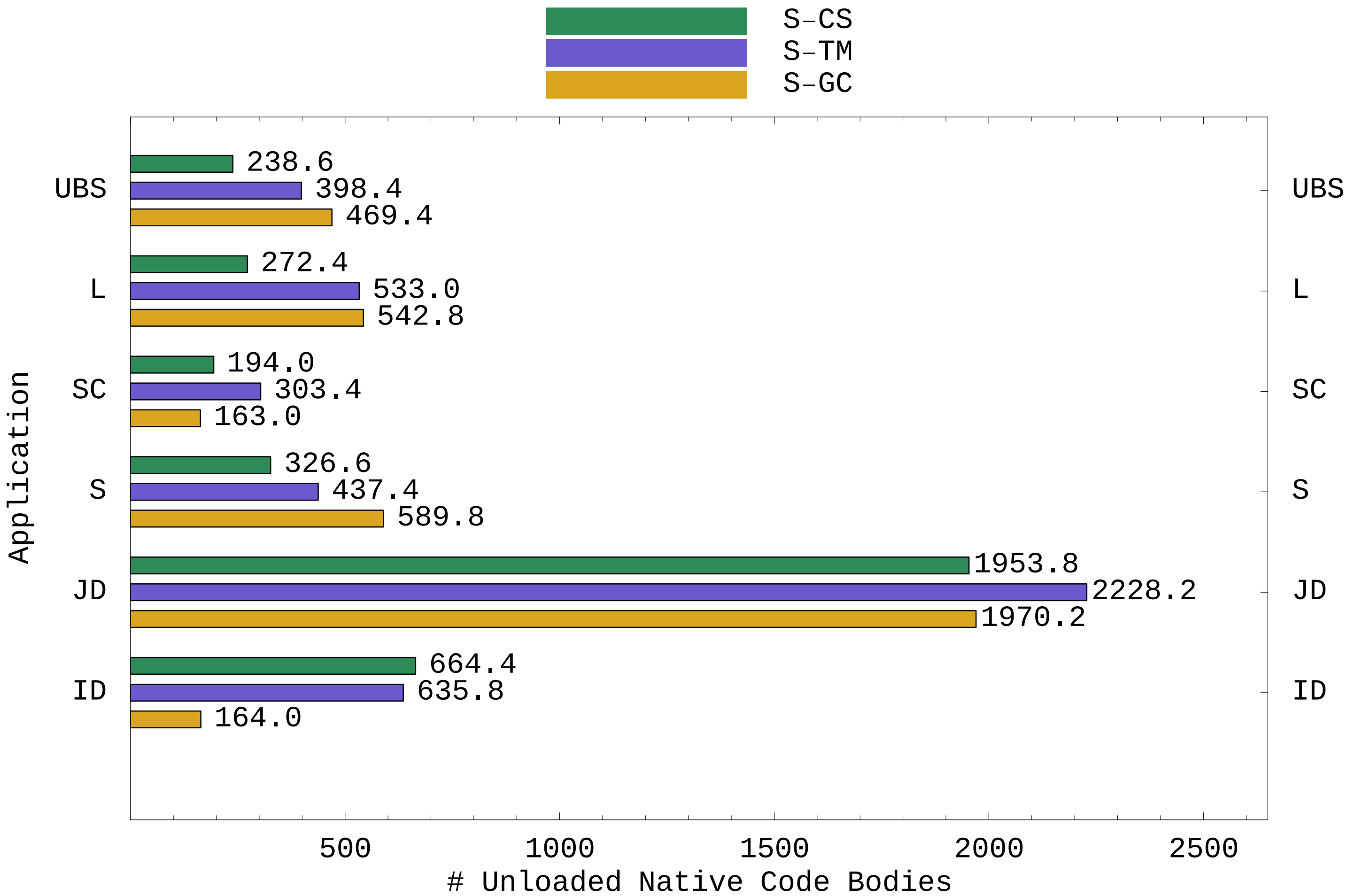
- Unloading can decrease code size while still creating an overall increase in testing time

Number of Code Unloads



- All techniques cause `ID` to perform few unloading sessions

Number of Unloaded Code Bodies



- ID's large working set forces unloading of many code bodies

Summary of Reductions

Name	$\mathcal{T}_R^{\%}(P,T)$	$\mathcal{S}_R^{\%}(P,T)$
S-GC	16.1	68.4 ✓
X-GC	16.4	52.8
S-TM	17.1	62.6
X-TM	16.4	45.9
S-CS	17.6 ✓	58.8
X-CS	15.3	54.8

- Across all applications, adaptive code unloading techniques reduce both testing time and space overhead

Conclusions and Future Work

- Dynamic compilation in JVMs can increase testing time if memory is constrained
- Adaptive unloading of native code often reduces memory overhead, avoids GC invocation, and reduces testing time
- Impact of unloading varies with respect to size of application’s working set and program testing behavior
- Regression test suite prioritization and reduction techniques that consider structural coverage *and* time and space overheads

Additional Resources

- Kapfhammer et al. Testing in Resource Constrained Execution Environments. In *IEEE/ACM Automated Software Engineering*. November 7 - 11, 2005.

http://cs.allegheny.edu/~gkapfham/research/juggernaut/